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ABSTRACT

The acquisition of information from pictures and the relationship between canonical orientation and the function of objects were studied. Twenty introductory educational psychology students experienced a set of five common objects, three different functional uses, and four possible orientations for each object. The results analyzed for one stimulus only indicate that the subjects spend more time on the first presentation of an object and rejects the hypothesis that subjects spend more time on features that are essential to the function being addressed. If the verification of functional uses follows from object identification, and the time to identify an object is greatest on the first presentation. Processing load in the illustration of texts and manuals can be minimized if attention is given to the initial presentation of an object. It is further concluded that the critical features of the object should be identified and displayed with the object in its most typical orientation. (PN)

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INTERRELATIONSHIPS OF CANONICAL ORIENTATION AND FUNCTIONAL GOODNESS OF OBJECTS: THE PERCEPTION OF FUNCTIONAL USES

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Cognitive psychologists have traditionally used introspection, reaction time, and eye scanning patterns to study the decision making process. The study reported here is a continuing attempt to understand the acquisition of information from pictures and the relationship between canonical orientation and the function of objects. According to the model of the perceptual cycle by Neisser (1976) comprehension can be thought of as a function of the stimulus, the manner of exploration of this stimulus, and the particular schema which is addressed. The series of studies which the author is currently conducting focuses on the picture, or illustration, and explores some of the kinds of information that is available in pictures and how this information is used in determining functional uses of objects.

Earlier studies in this series involved the selection of five common objects. These objects were a flower pot, a mitten, a paring knife, a wedge, and a cup. Multiple uses were assigned to these objects which were dependent on the orientation of the object. For example, a cup could be thought of as a holder of liquids in its normal position, a scoop if rotated approximately 90 degrees, or a trap for an insect if positioned up-side-down. Line drawings were made of the five objects and rotated in 45 degree increments generating a set of stimuli in which all features are constant and only the orientation of the object is varied. Subjects were asked to evaluate these drawings on a scale of 1 to 7 for canonical orientation (Palmer, et al, 1980) and for goodness of fit for each functional use assigned to each object. On these scales 1 was considered the highest rating, meaning that the object was most fit in that position, and 7 was a low rating, or the least fit position. These four scales, one of canonical orientation and three of functional goodness for each object, were used in all further experiments (figure 1).

Following the development of the above scales a study was conducted measuring reaction time required for deciding functional uses of these objects. Difficulty in interpreting the results of this study led to an attempt to confirm the canonical scale by using a reaction time to verify the identity of the objects in the various positions. It was most disconcerting to find that the cup was more readily recognized when it was in an inverted position. Repeating this study using mirror images of the previous stimuli provided results that are more readily interpreted (figure 2) but accepted with strong reservation on the part of the author who suspected that there was an additional variable as yet not identified.

The present study to be reported here focuses on eye-tracking data which is being used in an attempt to clarify and interpret the differing results obtained from the identity studies using standard and mirror images. The present study was designed to test the following hypotheses:

1. When making decisions as to functional uses of objects, subjects spend more time in scanning pictures on the first trial

than on successive trials.

2. Subjects spend more time fixating on features that are essential to the function proposed for that object than on features that are non-essential to the function.

3. The functional fitness of an object is highly correlated with the features fixated on.

4. The time spent fixating on a feature will increase as the object is removed from its canonical position.

METHODS: The following eye-tracking study was accomplished using the instrumentation and software developed in our laboratory (Hirschfeld and Bieger 1981). Eye movements were sampled at the rate of 60 ticks per second, converted to digital values and stored on floppy disks for computer analysis. These data were then sent by the computer to the plotter and converted to a graphic display of the subjects eye movements which could then be further analyzed for fixation positions and duration.

Stimuli: Each stimulus for this study consisted of a 3 inch by 3 inch square which contained a label centered at the top stating a possible functional use of the object. The central portion of the square contained a line drawing of an object. In the lower left corner was the word "yes" and in the lower right corner the word "no". These stimuli were created by digitizing line drawings of the five objects being studies plus four additional objects used as confusor items. Using the MAP program (Hirshfeld and Bieger), areas within the objects were identified as defining features of the objects. Figure 3 illustrates one of the stimuli, the cup, as it appears to the subject and as it is divided into areas for analysis of eye fixations.

A new computer program, ROTATE, was written which takes the digitized stimuli and rotates the object and its defined feature areas 90, 180, or 270 degrees but does not rotate the functional label area or the "yes" and "no" areas. The stimuli were then drawn by the plotter on 3 by 5 cards to be used in the eye track machine. Cards were constructed with objects in all four orientations. Three different functional statements were used with each orientation. Hence, a set of stimuli consists of five objects, three different functional uses, and four possible orientations for each object. This makes a total of 60 different conditions. Since presenting any one subject with all of these conditions would be too time consuming and too tiring for the subject the complete set of stimuli was divided into four blocks, with only one block to be presented to a subject. Each block contained stimuli depicting each object in three orientations but different function statements were assigned to these different orientations.

Subjects: The subjects for this study were 20 college students in an introductory eductional psychology course who were given course credit for their participation. The data from one of these had to be rejected due to improper adjustment of the eye-trac camera and the data from two others is irretrieveable due to computer hardware error. The remaining 17 provided a total of 37 cases for analysis. The data from these is presented and analyzed in this paper.

Task: The stimuli presented to the subject was initially screened by an eye-track adjustment card. After the initial adjustment file was made the subject was told to look at a star in the upper right corner of the screen until the screen was

removed. This provided a consistent starting point for each scanning pattern. On removal of the screening card the subject was instructed to read the functional label, look at the line drawing, make a decision whether the functional label and the drawing were in agreement, and to fixate on the "yes" or "no" response corner. After a two to three second fixation the subject was instructed to fixate on the label, the "yes", and the "no". These fixations were used for later adjustment of the eye-track data and to check for head movement during the task. Subjects were shown a block of nine stimuli and then permitted a brief rest before continuing with the experiment. There were three blocks of slides in all with two rest periods scheduled for each subject.

RESULTS: The results analyzed here will concern only the data for the cup stimuli. The four other objects are still being evaluated but preliminary analysis indicates that the results seem to be in agreement with those for the cup.

The cup has been defined into three areas, handle, rim, and base. Ticks were assigned to each of these areas according to the MATCH program (Hirshfeld and Bieger) starting with the first departure from the functional label area to the first fixation on the "yes" or "no" response. Fixations of less than 7 ticks (approximately 15 milliseconds) are not included under the assumption that these are saccades and no information is acquired from the simulus during this time (Neisser 1968). An example showing the eye movements plotted on the stimulus and its MATCH printout is shown in figure 4. In addition to measuring the fixation times for the various features of the stimulus the presentation order (trial) was also recorded since each subject saw each object three times during the course of the study. A subject never saw the object in the same orientation on successive trials so the position of the object was recorded by assigning the value obtained for that position from the rating scales developed for canonical orientation and functional goodness in the earlier study. The total number of fixations on the object was computed by adding the fixations for the three feature areas.

Examination of the means of the various feature areas shows the longest fixations on the handle area with fixations on the rim and the base decreasing in that order (figure 5). Due to large variability within these three groups (F-max = 60.9 with df = 36) an ANOVA is not an appropriate measure of variability. Correlation coefficients were calculated using SCSS (Nie et al, 1980) and are presented in figure 6. The only statistically significant correlations are between handle and trial (-.290 with df=35, $p < .041$) and between total and trial (-.364 with df=35, $p < .013$).

Further analysis using a 1-order partial correlation controling for the effect of trial gives a significant correlation between the canonical rating and handle (.312, $p < .032$) but no additional statistically significant results are obtained (figure 7).

DICUSSION: Examination of figure 5 reveals that more time is spent fixating on the handle area of the cup than any other area. This is interesting in that this feature is not essential for any of the functions assigned to it though a weak case could

be made that the handle is essential for the scoop function. Since an ANOVA is not reasonable with this data hypothesis 2 cannot be rejected on grounds that the fixation duration means of the different feature areas are significantly different. However, on examination of the correlations coefficients an interesting result is obtained. The negative correlation of trial with total fixations is significant as is the negative correlation of trial with handle. Neither of the two other areas is significantly correlated with trial. This allows the acceptance of hypothesis 1 that subjects spend more time on the first presentation of an object but it also requires the rejection of hypothesis 2 that subjects spend more time on features that are essential to the function being addressed.

Looking now at the partial aorrelations it is necessary to reject hypothesis 3 that the features fixated are correlated with the proposed function. It is especially worthy of note that the correlation between function and each of the feature areas is extremely low. An examination of the partial correlations (controling for trial) between the canonical scale and the features reveal that we cannot completely accept hypothesis 4 either. Only the handle is significantly correlated with the canonical scale.

From this set of studies it is proposed that subjects, when asked to make decisions verifying the possible functional uses of common objects, first assertain the identity of the object portrayed. To determine the identity of an object subjects fixate specific features that seem to be critical for the identification of that object. After the object has been identified subjects ther determine if the proposed function is one that the object can suitably perform. Therefore, if the verification of functional uses follow from object identification and the time to identify an object is greatest on the first presentation, in the illustration of texts and proceedural manuals, such as those used extensively in many types of instructional settings, processing load can be minimized if attention is given to the initial presentation of an object. If possible, the critical features of the object should be identified and displayed with the object in its most typical orientation.

This study also suggests further research on the relationship of function to canonical position. Since it has been suggested that specific features are critical features in the identification of an object, an additional study is proposed in which these critical features are manipulated to determine if the functional uses can be addressed directly without thc apparent accessing of the objects identity. The objects selected in this study were all small enough to be manipulated by hand and did not necessarily have fixed orientations. A further study might examine the effect of size and orientation on functional use decisions. This would involve pictures of objects that are too large to be manipulated or have fixed positions. These would be objects like house, boat, tree, mailbox, etc. A third proposed study would use unfamiliar objects. From this study it could be determined if subjects assign size and orientation to unknown objects and if critical features are identified on early trials and used to identify objects and determine object functions with minimal presentations.

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Figure 1.
Rating scales of the cup for canonical orientation and the three functional uses.

Figure 2. Canonical data for cup with its flipped image

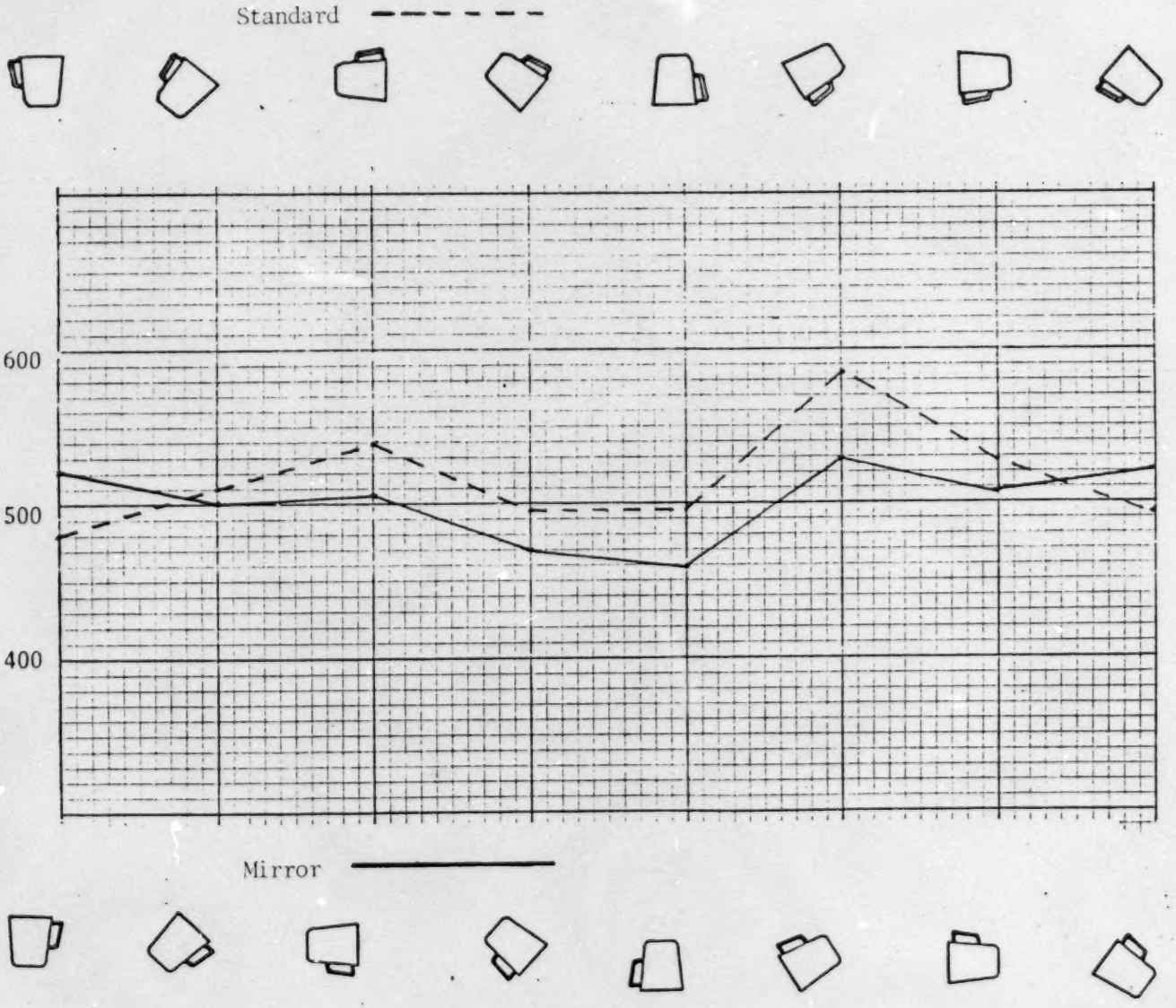
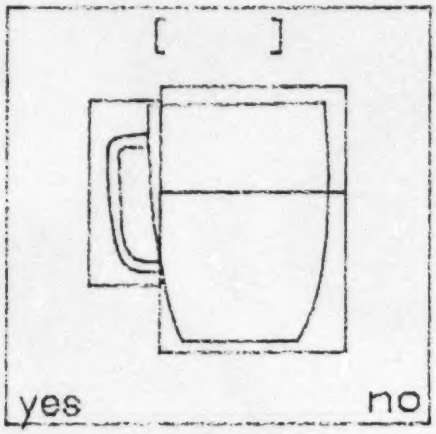


Figure 3.

Sample stimulus showing feature areas



Sample stimulus as it appears to the subject

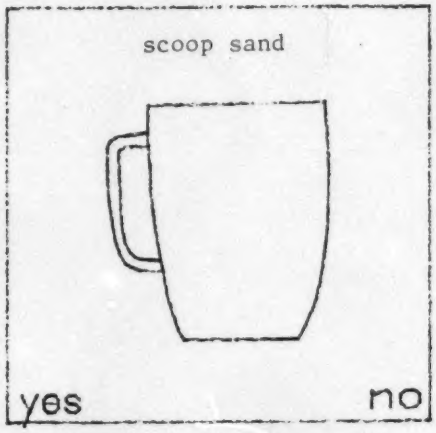
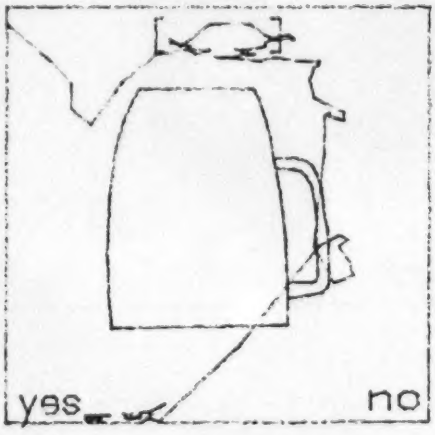


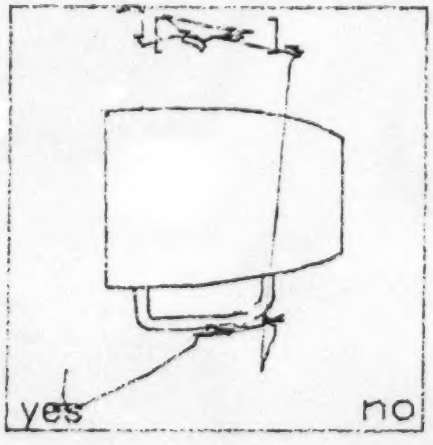
Figure 4. Two cases showing the plotting of eye movement data and the MATCH printout for the same data.

PLOTTED DATA



MATCH

```
30  [     ]
 1  "base
 4  [     ]
 3  "base
17  "handle
 1  "rim
 9  yes
```




```
50  [     ]
 1  "base
32  "handle
 9  yes
 6  "handle
19  yes
 9  "handle
107 yes
```

Figure 5.
Table of the means, variance, standard deviation, and per cent of total fixation time for the various areas of the cup stimulus.

AREA	MEAN	VARIANCE	STDDEV	DF	PER CENT
handle	20.000	1105.556	33.250	37	40.4
rim	13.243	510.467	22.594	37	26.8
base	16.196	686.245	26.196	37	32.8
total	48.595	3457.303	58.799	37	100.0

Figure 6.
Correlations between factors and the significance levels
(* .050 level, ** .010 level and *** .001).

FUNCTION	.557 .000***			
HANDLE	.254 .065	.061 .361		
RIM	-.054 .375	.013 .471	.289* .041	
BASE	.011 .457	.089 .300	.092 .294	.423 ** .005
TOTAL	.110 .258	.065 .351	.727*** .000	.745*** .000
TRIAL	.142 .201	-.043 .401	-.290* .041	-.253 .065
SUBJECT	.037 .415	.156 .178	.216 .099	.212 .104
	canonical	functional	handle	rim
TOTAL	.650 .000***			
TRIAL	-.271 .053	-.364* .013		
SUBJECT	.115 .249	.227 .049	-.082 .315	
	base	total	trial	

Figure 6.b
1-order partial correlations controling for trial.
significance levels: *.050, **.010, ***.001

FUNCTION	.569***			
	.000			
HANDLE	.312*	.050		
	.032	.385		
RIM	-.019	.002	.233	
	.456	.496	.085	
BASE	.051	.081	.015	.380
	.383	.320	.466	.011
TOTAL	.175	.053	.697***	.725***
	.153	.379	.000	.000

	canonical	functional	handle	rim
TOTAL	.615***			
	.000			

	base